Big Sand Lake Restoration Survey and Expanded Monitoring Small Planning Grant Final report.

Introduction. A DNR Grant of $3,000 including $1000 in local matching for a Landowners survey, Restoration, and Monitoring.

The goal of the Big Sand Lake Preservation Association is to care for the health of our lake. In accordance with this the above sum was awarded with $1,500 received together with $500 awarded upon completion. Matching funds for donated effort in the mount of 1,000 was required. . A survey to understand property owner's position on restoration was specified as well as some of the related monitoring efforts that the BSLPA had had proposed.

Landowner Survey. Permanent residents include Native Americans on properties administered by the St. Croix Chippewa Indians of Wisconsin and number about 150 individuals. Other landowners include about 100 mostly cabin owners. Residency is generally a few summer weekends per year with a half dozen permanent residences. Addresses of the landowners were obtained from public records and personal contact. There was no attempt to contact Tribal households but general positions are generally known. The Tribe maintains a formal environmental protection division that considers drainage policies, collects data used for effecting some lake use. Issues were discussed in both formal and informal meetings. Cooperation has been extensive. Appreciation of lake association efforts has been expressed verbally and in writing. No contentious issues or significant differences of opinion have emerged.

Circulation. The survey, reproduced below, was attached the *Sand Lake Observer*, Volume 2, No. 2, 2014, and circulated   to the approximately 100 landowners mentioned above. Scores ranked from 0 to 3 on questions ranged from a low of 2.00 on lake health monitoring to a high of 2.61 for reestablishment of wild rice. For vegetative buffers it was a very positive 2.67 ± 0.68; n = 19. Also most respondents (16) wanted to receive association minutes by e-mail, 13 would donate funds, but only 5 had time to donate.

Written comments were exceedingly positive as well and generally said "we like what you are doing". One thought catch and release would not work, and one was troubled by structural problems within the organization. A later e-mail indicated that these problems had apparently been resolved. Only one respondent, a member of our sister organization, was negative and exceedingly so. A survey copy and analysis follows:

Survey analysis; the survey:

Please indicate your level of support, little to strong: 0 , 1, 2, or 3

Instillation of fish sticks to help restore biological balance in Big Sand.
___0 ___1 ___2 ___3 **Response: Average 2.58 ± 0.71; n = 17**

Catch and release of northern pike (and walleye if established) is useful.
___0 ___1 ___2 ___3 **Response: Average Score: 2.53 ± 1.00; n = 17**

Re-establishment of wild rice in non-populated areas such as the west bay is useful.

___0 ___1 ___2 ___3 **Response: Average Score: 2.61 ± 0.61; n = 1.03**

Expanded effort to monitor the health of Big Sand including automatic lake levels, fish stomachs, fish sizes, invertebrates, phytoplankton is useful.
___0 ___1 ___2 ___3 **Response: Average Score 2.00 ± 1.03; n = 19**

Shoreline plantings friendly to wildlife and that intercept nutrients is useful.
___0 ___1 ___2 ___**3** **Response: Average Score 2.67 ± 0.68; n = 0.68**

Would like to receive board meeting minutes?
___No ___By e-mail ___By US mail __on www.bigsandlakepreservationassoc.org/

Responders preferto see minutes by e-mail 16 to 1.

Comments attached:

Six responders gave very strong support

One responder was concerned with organization structure and later gave strong support due to subsequent productivity.

One thought catch and release would not work, be mandatory or enforced.

One responder thought that most of the members should join the original lake association.

Ground cover. Lake frontages were examined by air and by boat. Aerial photography was by Piper PA-12 using a hand-held camera through an open window. Lake level images were taken by power boat. Locations of the Features are identified in Fig. 1. Aerial photos begin at the northwest point off the west bay and show the north shore. The photos are identified with the 22 images by legend.

Riparian buffers around the lake were further examined as shown in Table 2. Shoreline distances were calculated using a mean height of 60 feet for tree height and digital analysis of the images. The lake lies in a shallow basin on a plateau near the headwaters of the Big Sand watershed. Influent from surface water flow is therefore negligible. Most water throughput is by groundflow from the comparatively large watershed. This has buffered changes in lake level extremes to only about a foot over nearly a century. Most area lakes vary much more. Images run clockwise from the West Bay. Image “Public Landing” presented separately, shows lake frontage around the public access by landing by air, and image shows the same area from lake level. Figure “West Bay” (last aerial image) shows the track of rice seeding by the Tribe, and image 24 of the ground-level images shows an erosion mitigation structure installed by the Tribe.

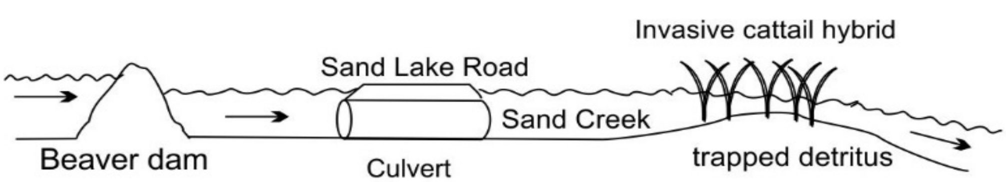
Only somewhat sparsely vegetated shoreline was photographed from lake level and amounted to about two miles of the seven mile shoreline. About 29% of that photographed from ground level appeared to be lightly vegetated as shown, and only 850 feet of or 7% of the approximately 12,000 feet of tree and brush free beach were lined with stone or gravel. Past erosion was evident at only two sites, both of which had been mitigated by the Tribe. The aerial images show the plethora of docks protruding from shore. Shallow beeches surround much of Big Sand and the docks ease access to boats. However studies show that dock density correlates with reduced habitat, biodiversity and lake health.

Table 1. Length of lightly vegetated lakeshore around Big Sand Lake.

Image number	Length, feet	Image number	Length, feet	Image number	Length, feet	Image number	Length, feet
1	71.	11	82	21	81	31	220
2	117.	12	248	22	642	32	750
3	161.	13	409	23	98	33	154
4	260.	14	450	24	60	34	202
5	450	15	338	25	83	35	500
6	150.	16	128	26	642	36	642
7	150,	17	281	27	535	37	326
8	60.	18	281	28	200	38	450
9	105.	19	642	29	268		**3,244**
10	162.	20	642	30	562		
	1686		3501		3171	Total =	**11,658**

Water Chemistry. To better understand the chemistry of Big Sand water, we considered we source water and flow, fish kills, wild rice dynamics, and nutrient limitation. Big Sand was a drainage lake before about 1930 and gradually became a seepage lake due to influent blockage from Warner Lake by Highway 70, effluent blockage by Sand Lake Road, and diversion of water from the watershed to the southeast to Clam River. Algal blooms from memory appear to have been slightly more intense then than at present. That could have been due to enrichment from a cranberry marsh contained due to natural nitrogen and phosphorus, chemical fertilization, or both. Calcium concentrations could not be located but a limnologist suggested that Big Sand is a soft water lake which implies concentrations that are low.

Water Flow out Sand Creek has been diminished by chronic blockage near and under Sand Lake Road. Addition of culverts last summer improved flow. However flow was diminished by a new beaver dam upstream, the culvert themselves, and cattails, likely an aggressive hybrid. Flow as insufficient to clear a waterway.



The dense vegetation filtered out detritus in the flow. The deposits raised the creek bed a foot or two over the sand bottom blocking flow and breaking communication with the Yellow River system. The flow of forage fish including redhorse suckers was then blocked impacting food webs in the lake. The accumulating detritus also may have increased oxygen consumption and reduced input oxygen from the lake proper leading to the first fish kill as reported in the TryCounty Leader and the Sand Lake Observer archived on our web site.

Water Quality. Clear water is a hallmark of Big Sand. The main water input is indirect from precipitation over a fairly large water shed of approximately 10 square miles in the form of ground-water flow. This pure water flows into the lake from the south and out to the west has buffered seasonal changes in lake level to about a foot since the 1930's. It also favors a calcium-poor softwater lake that may resist infection by zebra mussels that need calcium for shells. There is little nutrient input from farming, surface runoff is negligible due to the shallowness of the watershed, and nutrient seepage from surrounding septic tanks has been reduced by the improved designs required. Also the lake is covered with weed beds due to a shallow mean depth. Plants, phytoplankton and macrophytes sequester most dissolved nutrients and deposit them into the sediments. The result is clear water with Secchi disc readings of about 10 feet. This indicates a trophic level near oligotrophy, the clearest of four common levels. This results in rather low productivity due to populations of phytoplankton that are low.

Dissolved Nutrients. The productivity of fish and other living material in lakes depends on plants at the base of the food chain, mostly phytoplankton. But plants including wild rice depend on the same nutrition: nitrogen, phosphorus, carbon dioxide, and light. Mineral limitation is most common. Most literature identifies nitrogen as the limiting nutrient for wild rice. Wild rice is of particular importance of our Native American culture on Big Sand. However it is disappearing here as elsewhere. Although quite shallow, harvests have never been very large at least since the dust bowl years and have diminished ever since. In the 40's, about 30 pounds could be harvested in a day; 10% of current production on a good lake. To determine why, we fertilized test chambers with combinations of minerals. Among those that supported wild rice, only those amended with phosphate sported growth would grow as measured by stem (tiller) diameter at the water line (Table 2).

Table 1. Effect of mineral amendments on Wild Rice growth according to stem diameter.

Nitrogen	Phosphorus	Phosphorus + nitrogen	Unamended control
Sprouted but none emerged from the water	7.1 ± 1.3, n =7	8.2 ± 2.1, n = 7	Sprouted but none emerged from the water

Various test plots were seeded each of the following years that included addition of rice straw, stirring up sediments and spot seeding. Almost none emerged. There were a few scattered small patches, possibly associated with a fish or other carcass. Most turned red, a sign of phosphorus deficiency, and died. Image "West Bay Track" in the supplement shows tufts of rice that emerged and died in and extensive seeding, presumably due to phosphorus deficiency. A good stand results east of Indian Point near shore. Likely there is enough phosphorus in runoff from the short but seep bank. It will even grow in pure sand there near shore as shown to the right.

While abatement of phosphorous input is a goal of most lakeshore restorations, it appears not to be useful in Big. However there are other significant reasons to minimize shoreline disturbances including improvement of the connection between terrestrial and aquatic habitats. These improve both biodiversity and food web exchanges through. Two examples are insect and their larvae and amphibians which depend on both aquatic and land-based environments.

Phytoplankton: While phytoplankton are at the base of the food web in Big Sand, they are not currently monitored. Secchi Disc give a good indication of populations, but not of the speciation. For example harmful algal blooms are increasing in most states with both increased phosphorus and our warming climate. Table shows some species identified in Big Sand around the year.

Preliminary analysis of Big Sand phytoplankton speciation

Date	**Species**	**Division**
1/19/13	Chlorococcum	Chlorophyta
1/19/13	Asterionella	
	Westella	Chlorophyta
	Planktolyngbya	Chlorophyta
	Gleocystus	Chlorophyta
1/12/14	Synedra	Bacillariophyta
	Asterionella	Bacillariophyta
	Celostrum	
	Closterium	Chlorophyta
	Navicula	Bacillariophyta
	Ceratium	
	Synechococcus	Cyanophyta
	Frustulia	Baccillariophyta
	Ceratium	Pyrrhophyta
1/17/14	Pandorina	
	Glenodinium	
	Nitzschia	Bacillariophyta
	Peridinium	Pyrrhophyta
211/14	Anabaena	Cyanophyta
	Aphanizomenon	Cyanophyta
	Gyrosigma	
	Tolypthrix	
3/30/14	Tribonema	Chrysophyta
	Tabellaria	Chrysophyta
	Pithophora	Chlorophyta
	Mesotaenium	
	Oophila	

	Frustulia	Bacillariophyta
	Microcystis	Cyanophyta
	Coelastrum	
7/7/14	Schenedesmus	
	Microcystis	Cyanophyta
	Rhodomonas	
	Monoraphidium	
	Synedra	
	Rhodomonas	Cryptophycophyta
7/3014	Euglena	Euglenohyta
	Rhodomonas	Cryptophycophyta
	Merismopedia	
	Oedogonium	
	Microcystis	Cyanophyta
	Nostoc	Cyanophyta
8/5/14	Volvox	Chlorophyta
	Gonyostomum	Ochrophyta
8/10/14	Chrysophaerella	
	Gleoeocystis	
	Kirchnerilla	
	Anabaena	Cyanophyta
	Nostoc	
	Gonystomum	
	Fragilaria	Bacillariophyta
	Pandorina	Chlorophyte
8/31/14	Nistoc	
	Gonystomum	
	Fragilaria	Bacillariophyta
	Aulacoseria	Bacillariophyta
	Frystylia	Bacillariophyta
	Anabaena	Cyanophyta
	Oscillatoria	Cyanophyta
9/21/14	Chroococcus	
	Nitchia	Bacillariophyta
	Microcystis	Cyanophyta
	Cyclotella	Bacillariophyta
	Rhodomonas	Cryotophyces
	Chlamydomonas	
	Amphenozomnon	Cyanophyta
10/27/14	Volvox	Chlorophyta
	Frustucia	
	Scenedesmus	Chlorophyta
1/24/15	Chlorocluster	
	Coelastrum	
	Gomphonema	Bacillariophyta

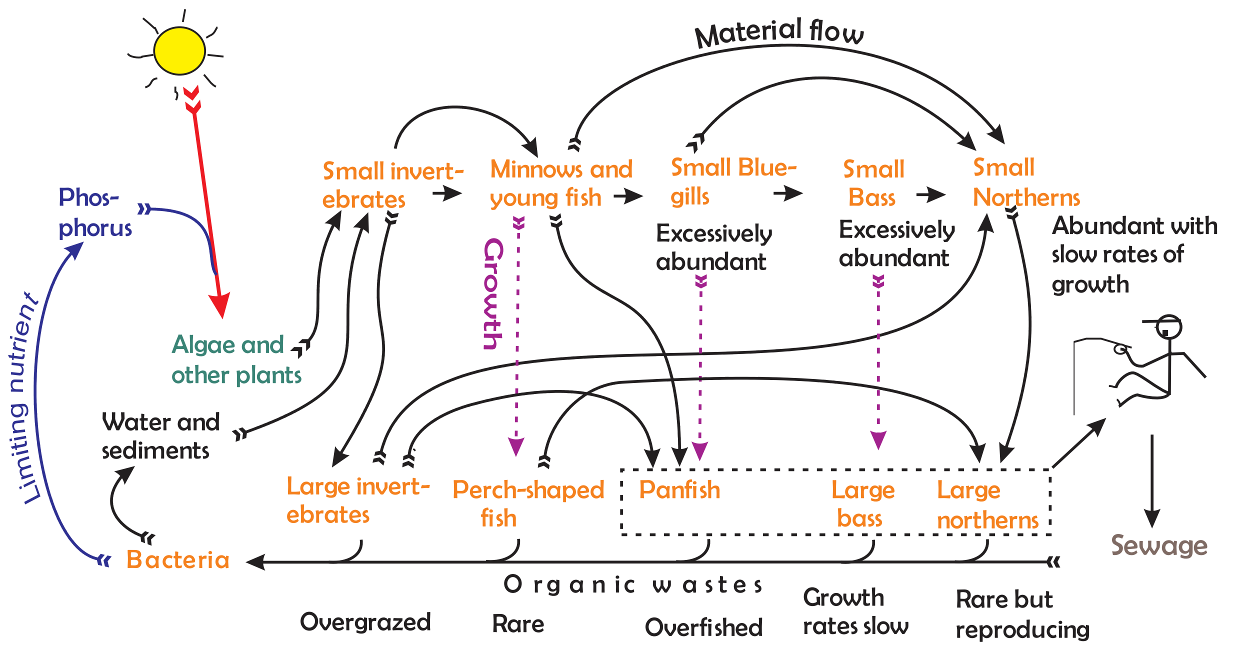
	Coscinodiscus	
	Hemidinium	
	Chlorococcum	Chlorophyta
	Selenastrum	Chlorophyta
	Nitzschia	Frustulia
	Dinobryon	
	Nostoc	Cyanophyta

Some were collected by net. Others were bucked sampled, most through the ice, Treated with iodine, allowed to settle usually three times in succession over three days, collecting the lower fraction, identified by microscope in wet mount, and photographed through a Leitz microscope mated to a digital recorder with a BEST custom coupler with internal vignetting-reduction lens.

Noteworthy was the significant Cyanobacterial content, even during winter. An iridescent metallic green sheen suggestive of cyanobacteria appeared in 2013. These “blue-green algae” can kill dogs and harm humans, but not all are toxigenic. In this case the particular species of the Cyanophyta group was not identified

Models. A good understanding of how lakes such as Big Sand function requires that the movement between the various life forms be expressed in quantitative terms. To begin that process we used available information to suggest critical connections between those that share in the distribution between nutrients and energy.

Major flows of energy in Big Sand



Winners and loosers

Walleye	extirpated	Yellow perch	increasing	Bluegills	dwarfed	Fishers	increasing
Large northerns	threatened	Geese	increasing	Crappie	dwarfed		
Clams	threatened	Diving waterfowl	decreasing	Bass	dwarfed		
Bullheads	threatened	Chinese snails	invading	Northerns	dwarfed		
Mayfly nymphs	threatened	Wild rice	decreasing				
Invertebrates	overgrazed	Reed Canary grass	invading				

Beginning with algal production from sunlight and minerals, energy moves up through the food chain through various invertebrates, on through fish, with humans as a major sink. Some of the interconnections are shown andthe food chain becomes a web. The return flow, the products of digestion, are harvested by bacteria and returned to the water as minerals. These energy and carbon rich organic compounds are used by phytoplankton and other photosynthetic organisms including macrophytes (sea weeds) and cyanobacteria. As the lake evolves over time and under the competitive pressures of other organisms including humans, some increase, others decrease, and many change. The result is winners and losers as shown. One surprising newcomer is yellow perch. These were always present but their particularly large size is new.

Key Findings:

1) The Big Sand Lake Landowner survey showed near unanimous support for efforts of the Big Sand Lake Preservation Association's efforts to maintain lake health of Big Sand including lakeshore restorations.

2) Images showed that some lake-fronts might be improved by vegetative restorations but they were limited, and only 7% of those were mineral surfaced. Main results improvements would be a stronger riparian connections and limited reduction in shoreline erosion.

3) Bioassays showed the lake to be phosphorus limited so that runoff abatement is paradoxical. Increased density of littoral vegetation would reduce shoreline erosion, strengthen the terrestrial link to the aquatic community, and improve biodiversity. Conversely the trophic status trends toward oligotrophic so that greater water transparent might clarify water transparency, but productivity of the already under-fed fishery might be further reduced.

4) Invasion by foreign species often appears to first depend on properties of the lake properties such as physical features and water chemistry. For example, iBig Sand, if it is a soft water lake low in calcium, might resist invasion by zebra mussels.

5) A series of impediments to water flow due from road and other projects has converted Big Sand from a drainage lake to a seepage lake which has harmed water chemistry and decreased productivity.

6) Morphology is diverse with deep refuges extensive shallow weed beds improving attractiveness to fish and wildlife.

7) Anthropogenic overfishing has led to dwarfing, extinctions, threatened populations including the top piscivore (northern pike) and reduced opportunities to catch large Fish.

8) Increased corn crops has bolstered geese populations that use Big Sand as a migratory respite damaging rice beds and, as carriers of schistosomes, increasing the presence of swimmers itch.

9) Invasion by alien species is comparatively limited. Largemouth bass and black crappie were introduced as sport fish, reed canary grass was introduced as cattle feed, and a few invasive large snails have appeared.

10) Cyanobacteria are surprisingly abundant and persist throughout the year.

11) Big Sand appears to be striving for new equilibria in response to various anthropogenic insults. Over the years excess populations have shifted from small northern pike to small sunfish, and then to small bass. Reed canary grass and hybrid cattails are gaining. And a good population of large yellow perch is becoming established. Mayflies, once numerous, along with their larva as a major food stock along with frogs and clams and wild rice are in decline.

12) Climate change and associated warming could impact Big Sand with Northern pike near its upper temperature limit and dense Cyanobacterial blooms, along with associated toxins could become problematic. Ecological upsets sometimes called regime shifts such as can be initiated by infestation by common carp cold occur.

Matching fund donations

Date	Activity	Name	Time	Rate	Total
8/10/15	Aerial Survey	Button	0:45	200/hr	150
8/10/15	Boat Survey	Button/Patnaude	0;45	200/hr	150
Table ____	Phtoplankton analysis	Button	14 samples X 10 hrs	$50/hr with Labatatory	700
And much more					1,000

Strategy going forward.

Following are plans based on results from the planning grant. The common thread is that the main threats to the health of Big Sand, invasion by alien species, habit destruction, and selective removal of the most robust individuals of various species are mostly man made.

Species invasion. Although interlake transfer by bait or boat is likely, few new fully aquatic species are apparent. The main resistance may be a healthy lake with insufficient empty niches and suitable chemical and physical properties for fascile invasion. For example common carp, long established in Yellow River just two miles downstream, have failed to establish a population of breeding fish. New evidence suggests that mineral concentrations, sediment content, and turbidity can all affect invasions. Thus understanding invasive threats requires some new measurements such as the levels of calcium, iron, and algal toxins, the properties of sediments, and deep water turbidity.

Also new species invasion may not be all bad. New genetic information added which may simply speed evolution toward an increase in total biomass because maximizing biomass from available resources is a major driving force in nature. Also a new species can add to species diversity, the hallmark of a healthy ecosystem. So the invasion could be more of a short term problem and the new species may fit in better over time as it becomes prey for a new predator perhaps normally present in the invaders original home. While this of little solace to a cabin owner worried about next year's picnic, Europe has recovered, in quite a few cases, from a lot of species exchange. Carp has become a sought-after and productive sport fish.

Shoreline restoration. Most of the shoreline of Big Sand is vegetated by native species, and nutrient runoff appears to be unproblematic. However there is room for improvements and financial support to do so for part of the waterfront is available. Some shoreline is eroded, some has little vegetative buffer to limit erosion and support ecological exchanges, and some might profit by replacing mineral waterfronts with some firmly rooted plants. The density of docks is high and evidence indicates a negative impact on lake ecology. In many cases the gently sloping beach makes a somewhat lengthy dock convenient, even for craft of modest draft.

Understanding Big Sand. Support of research on lake health, unlike human health, is insufficient for the task at hand. Government funding for understanding our lakes, for example, is below 0.1% of that for human health. A telling statistic is that foreign authorship in the lead American *Limnology and Oceanography* at has risen to 62% although European and other limnological journals continue to abound. It is therefore not surprising that basic concepts in how our lakes function lags. Interactions among aquatic organisms can be likened to those among the organs of the human body. Both are complex, but only those of the human body have enjoyed the support necessary for detailed descriptions.

Most useful for understanding lake is a measurement based mathematical model of the biological organisms contained. A conceptual model based on synoptic observations of Big Sand (Fig. __) attempted to show energy flows and feeding responses. More useful are models that reflect actual flows. Recent advances in the construction of such models have been pioneered in Europe. This association is making certain contributions to the modeling of competition for nutrients as well. One goal is to utilize this new knowledge in a way that helps generate better management decisions for the lake. We propose to continue improve real time observations in the form of fish stomach analysis and phytoplankton characterization.

Fishery improvement. A significant immediate problem is selective removal of the largest members of the several fished species. It has led to dwarfing, slow rates of growth, and ecological imbalances. We therefore propose to encourage a culture of catch and release modeled around some of the successes experienced in Minnesota and particularly in Canada.

Historical changes. Niow with experience in identifying trends in the populations of phytoplankton, we plan to examine the record of diatom sizes left in the sediments. The main goal is to help correlate lake health with the rather recent increases in human populations over the last two centuries.